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Gardes et al.

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(54) **TURBOFAN COMPRISING A SET OF ROTATABLE BLADES FOR BLOCKING OFF THE BYPASS FLOW DUCT**

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CPC ***F01D 7/00*** (2013.01); ***F01D 25/24*** (2013.01); *F05D 2220/323* (2013.01); *F05D 2220/36* (2013.01); *F05D 2240/60* (2013.01); *F05D 2260/30* (2013.01)

(58) **Field of Classification Search**
CPC F02K 1/09; F02K 1/64; F02K 1/70; F02K 1/72; F02K 1/763; F01D 7/00; F01D 25/24
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,933,890	A	4/1960	Morrison	
4,137,711	A *	2/1979	Montgomery	F02K 1/72 60/226.2
9,074,554	B2 *	7/2015	Caruel	F02K 1/763
10,830,089	B2 *	11/2020	Gardes	F01D 17/167
2017/0198658	A1	7/2017	Higgins	

(Continued)

FOREIGN PATENT DOCUMENTS

DE	1937679	A1	2/1971
FR	3067760	A1	12/2018

OTHER PUBLICATIONS

French Search Report; priority document.

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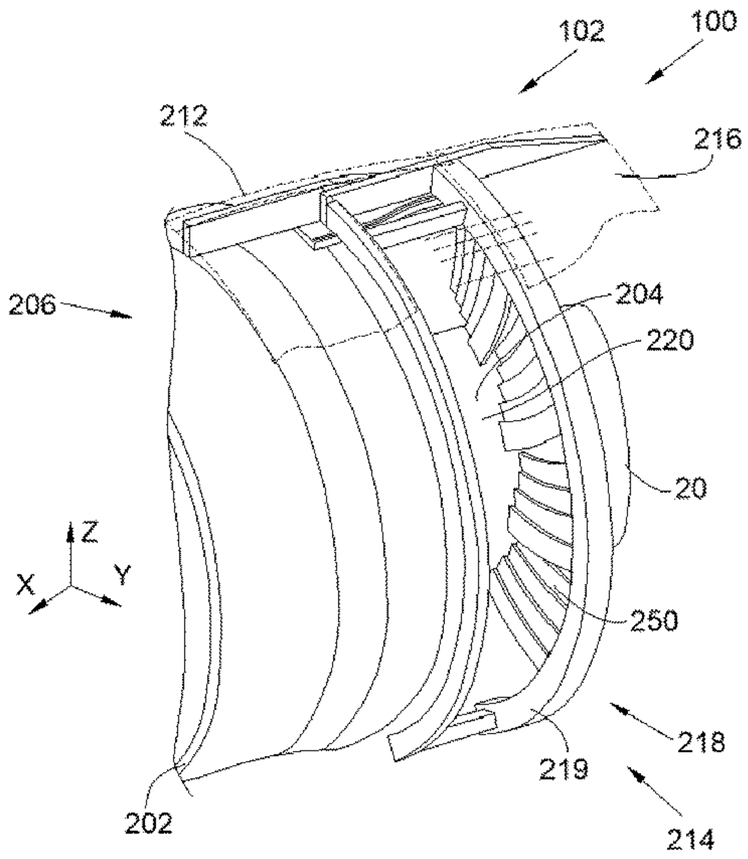
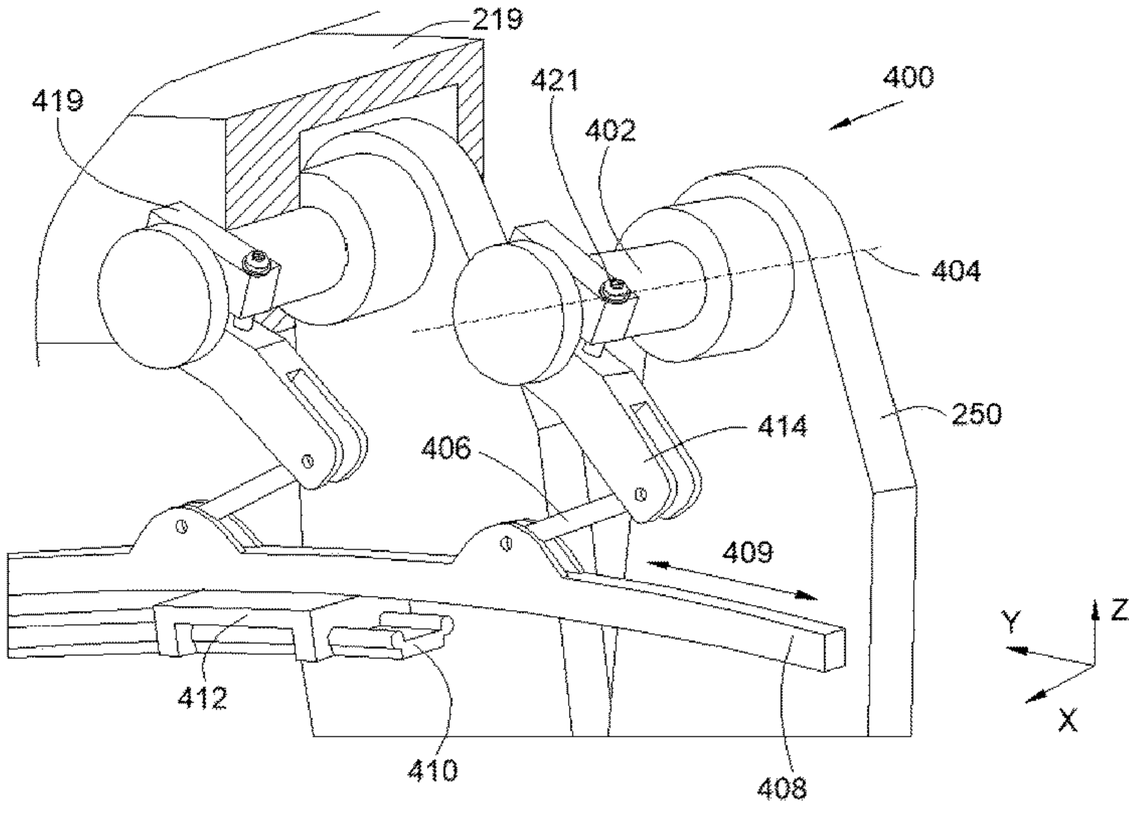
(57) **ABSTRACT**

A turbofan having a nacelle including a slider mobile in translation between advanced and retracted positions to open a window between a duct and the exterior, a plurality of blades, each being mobile in rotation on the slider between stowed and deployed positions, and a maneuvering system that moves each blade and includes, for each blade, a shaft mobile in rotation on the slider and on which the blade is fixed, an arm having a first end fixed to the shaft and a second end, an arc which is coaxial with the longitudinal axis and is rotatably mounted on the slider, about the longitudinal axis, a lever mounted in articulated fashion between the arc and the second end of the arm, and an actuation system which rotates the arc in one direction and in the other.

3 Claims, 3 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

2018/0372025	A1	12/2018	Ridray et al.	
2020/0325848	A1*	10/2020	Gardes	F02K 1/09
2021/0017935	A1*	1/2021	Cazeaux	F02K 1/72

* cited by examiner

Fig. 1

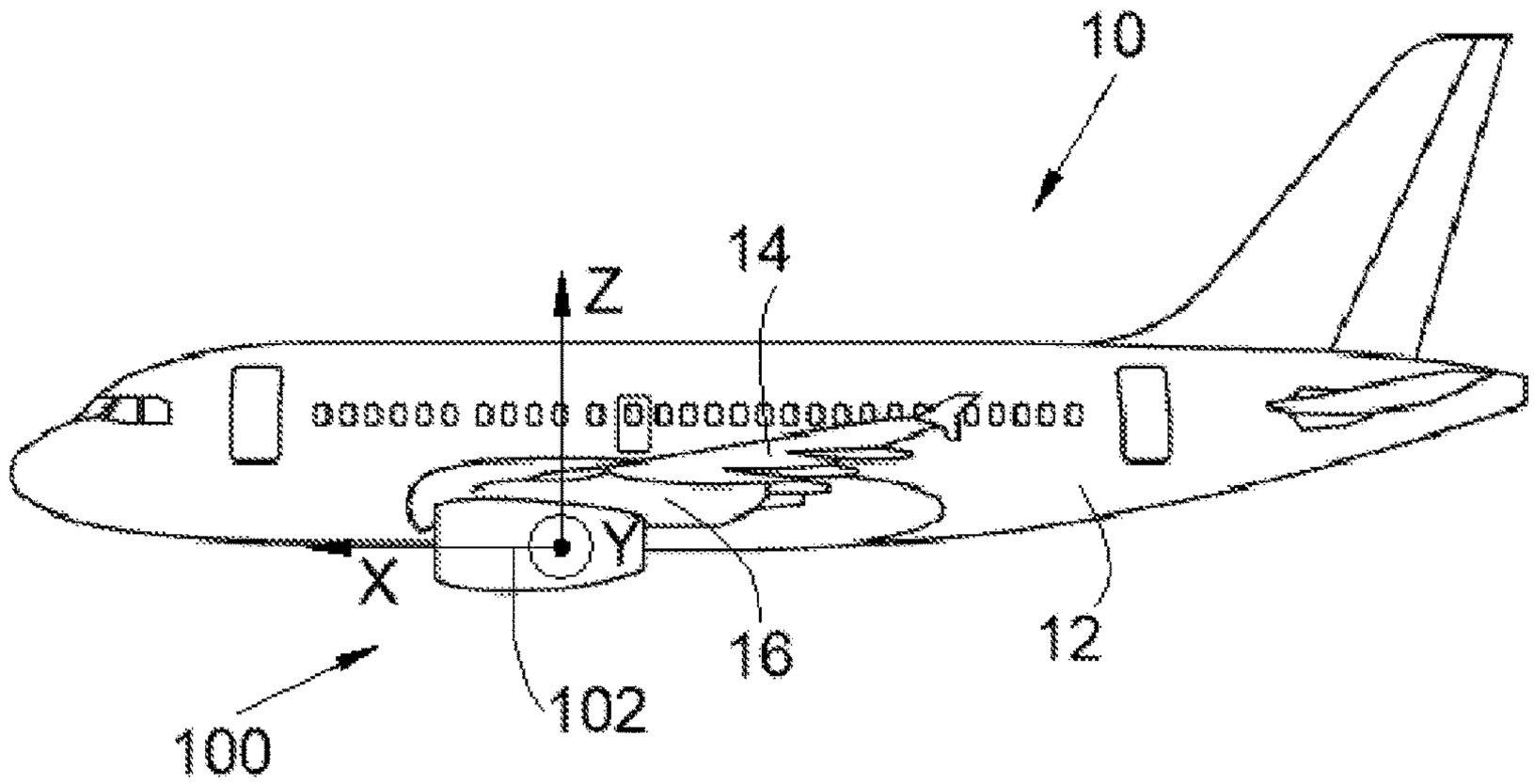
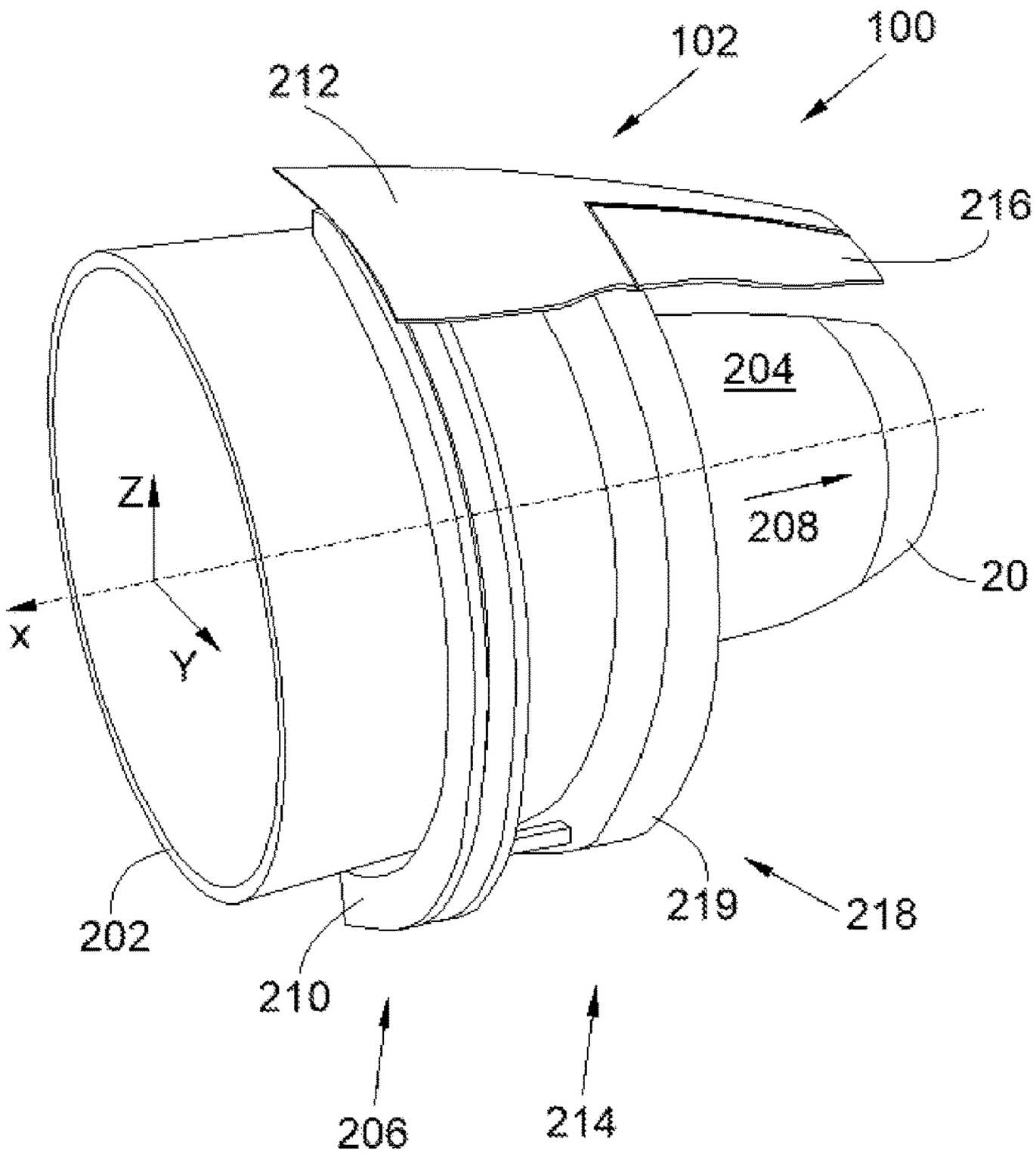

10
14
Z
Y
X
16
12
102
100

Fig. 2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100
212
216
204
208
20
Z
X
Y
202
210
206
214
219
218

Fig. 3

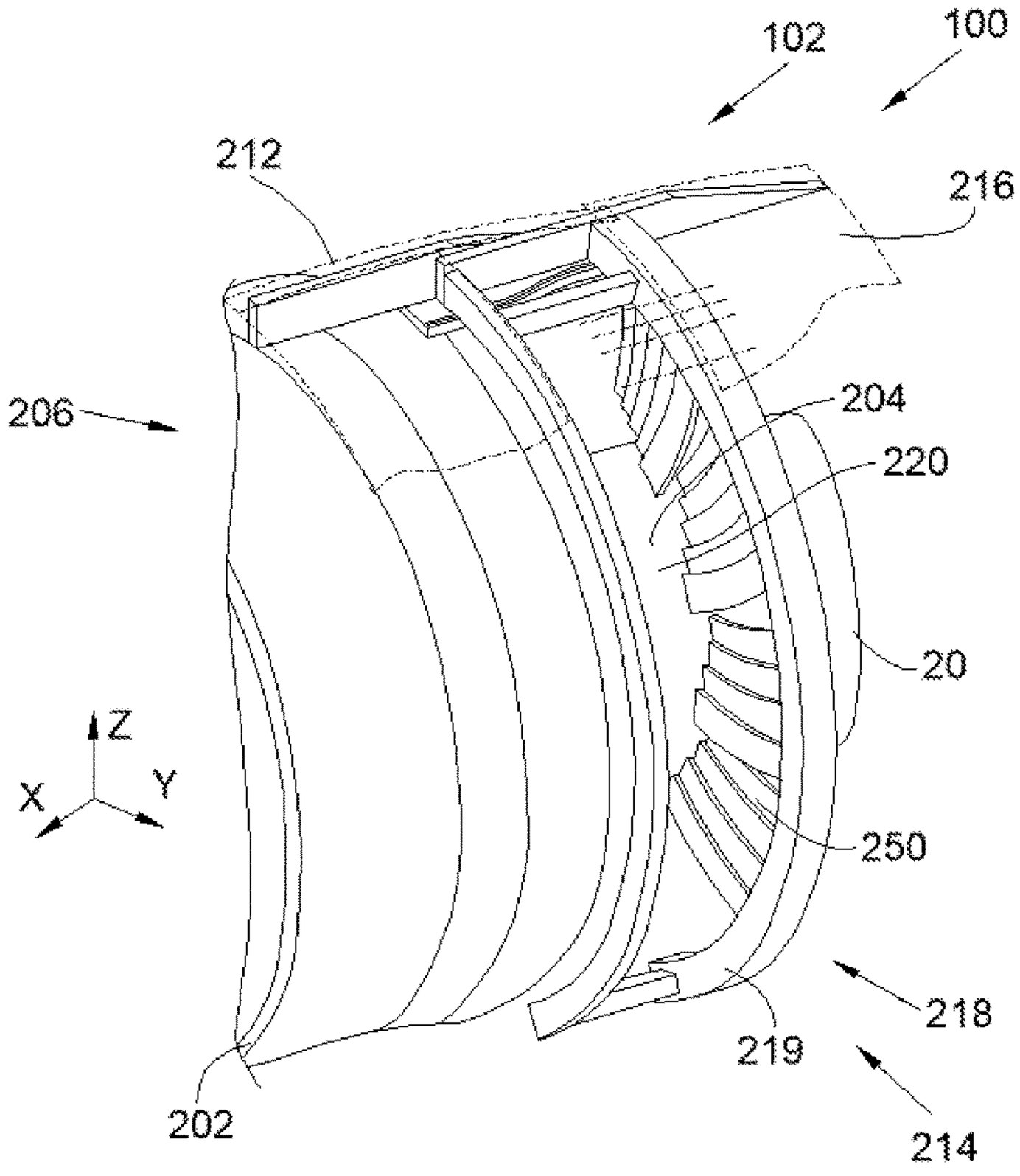
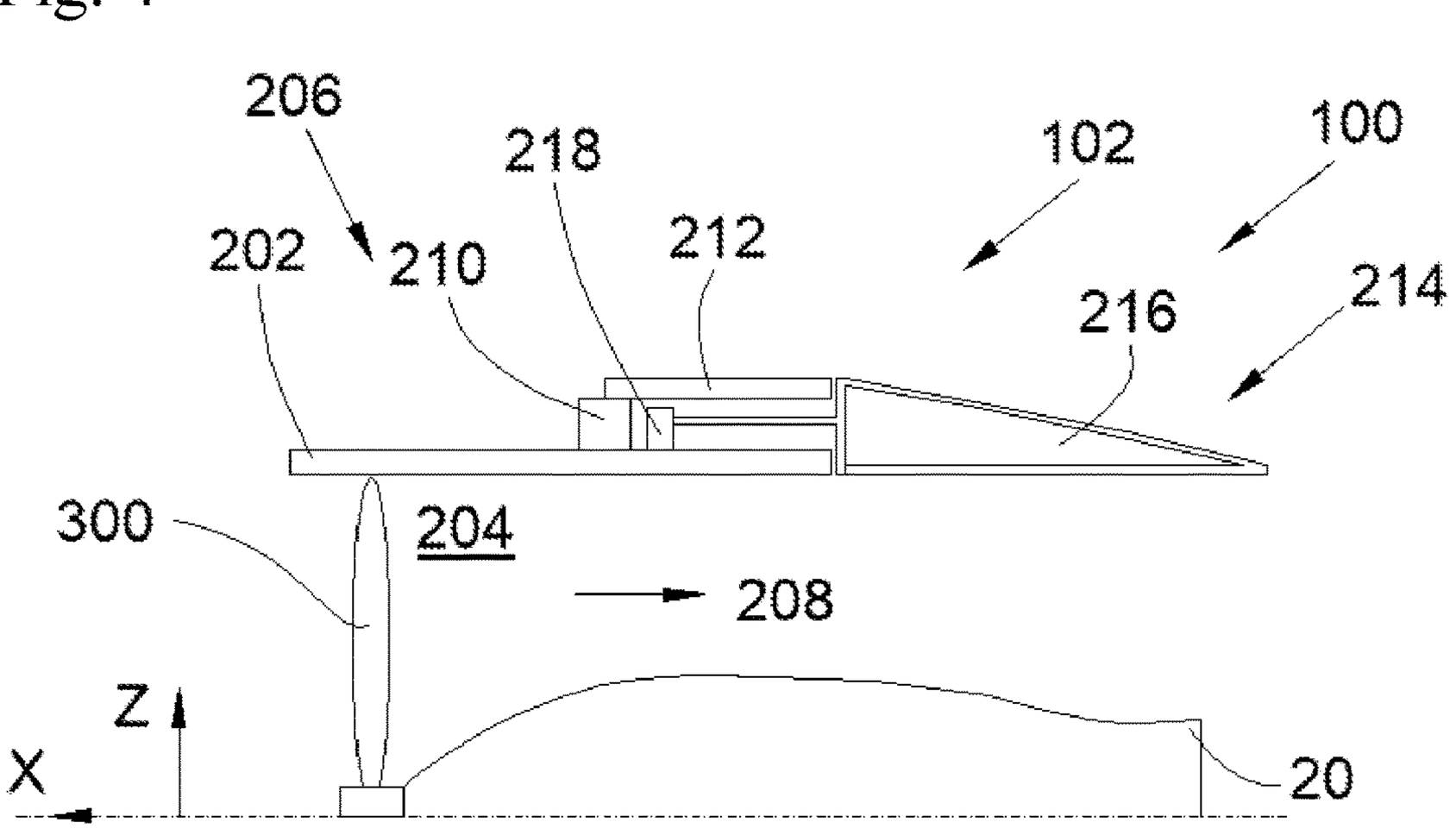

102
100
212
216
206
204
220
20
Z
X
Y
250
218
219
202
214

Fig. 4


206
218
102
100
202
210
212
216
214
300
204
208
Z
X
20

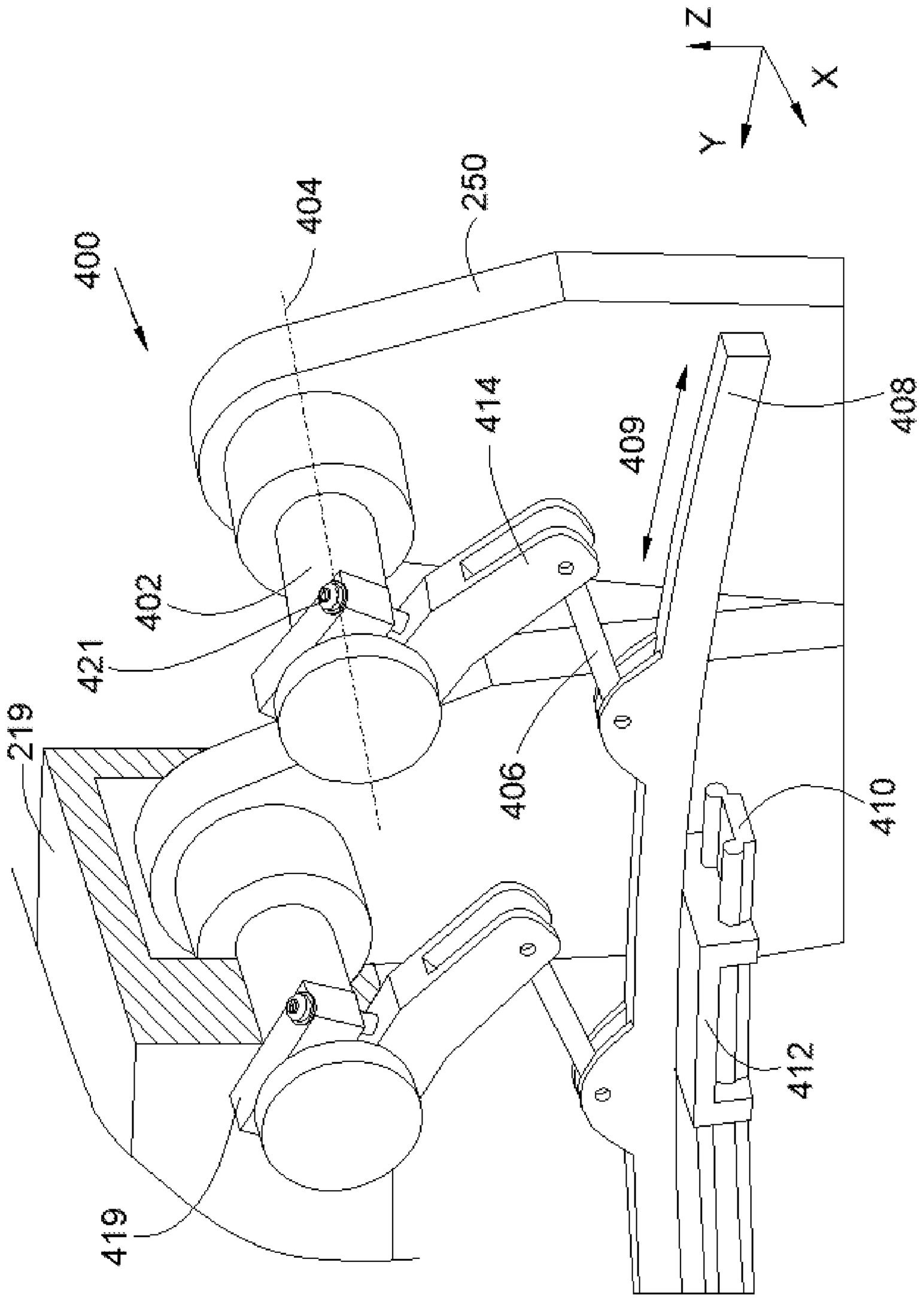


Fig. 5

TURBOFAN COMPRISING A SET OF ROTATABLE BLADES FOR BLOCKING OFF THE BYPASS FLOW DUCT

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of the French patent application No. 1903068 filed on Mar. 25, 2019, the entire disclosures of which are incorporated herein by way of reference.

FIELD OF THE INVENTION

The present invention relates to a turbofan which comprises a set of blades which are mounted so as to be able to rotate in order to block the duct for the bypass flow, and to an aircraft comprising at least one such turbofan.

BACKGROUND OF THE INVENTION

An aircraft includes a fuselage to each side of which is fixed a wing. Under each wing is suspended at least one turbofan. Each turbofan is fixed under the wing by means of a pylon that is fixed between the structure of the wing and the structure of the turbofan.

The turbofan comprises a motor and a nacelle that is fixed around the motor. The turbofan has, between the nacelle and the motor, a bypass duct in which a bypass flow flows.

The nacelle comprises a plurality of reversal doors, each one being mobile in rotation on the structure of the nacelle, between a stowed position in which it is not in the bypass duct and a deployed position in which it is positioned across the bypass duct in order to redirect the bypass flow towards a window which is in the wall of the nacelle and which is open between the bypass duct and the outside of the nacelle.

Thus, the bypass flow is redirected to the outside and more specifically towards the front of the engine in order to generate reverse thrust. Moreover, each reversal door is moved using a connecting rod which crosses the bypass duct in the stowed position and which thus partially blocks the bypass duct.

Although the reversal doors are entirely satisfactory, it is desirable to find different mechanisms, in particular mechanisms which are more lightweight and which in no way obstruct the bypass flow when in the stowed position.

SUMMARY OF THE INVENTION

One object of the present invention is to propose a turbofan which comprises a set of blades which are mounted so as to be able to rotate in order to block the duct of the bypass flow.

To that end, a turbofan is proposed having a longitudinal axis and comprising a motor and a nacelle, surrounding the motor, which comprises a fan casing, in which a duct for a bypass flow is delimited between the nacelle and the motor, and in which a flow of air flows in a flow direction, said nacelle comprising:

- a fixed structure fixed to the fan casing,
- a mobile assembly having a mobile cowl and a slider, the mobile cowl being fixed to the slider, the slider being mobile in translation, on the fixed structure, in a direction of translation between an advanced position in which the slider is positioned such that the mobile cowl is moved close to the fan casing and a retracted position in which the slider is positioned such that the mobile cowl is moved away from the fan casing so as to define, between them, an open window between the duct and the exterior of the nacelle,
- a plurality of blades, each one comprising a first end mounted so as to be mobile in rotation on the slider about an axis of rotation, and where the blades are angularly offset from one to the next about the longitudinal axis, wherein each blade is mobile between a stowed position in which the blade is outside the duct and a deployed position in which the blade is across the duct,
- an assembly of actuators causing the slider to move between the advanced position and the retracted position, and vice versa, and
- a maneuvering system intended to move each blade from the stowed position to the deployed position and vice versa, where the maneuvering system comprises:
- for each blade, a shaft mounted so as to be mobile in rotation on the slider about an axis of rotation, and on which the blade is fixed,
- for each shaft, an arm which has a first end fixed to the shaft and a second end,
- an arc which is coaxial with the longitudinal axis and is mounted so as to be mobile in rotation, on the slider, about the longitudinal axis,
- for each arm, a lever mounted in articulated fashion between the arc and the second end of the arm, and
- an actuation system which rotates the arc in one direction and in the other.

An engine of this kind permits a reduction in mass by replacing the reversal doors and their drive mechanisms with more lightweight pivoting blades having a simplified maneuvering system.

Advantageously, the first end of each arm takes the form of a pair of pincers that grip the shaft and comprise a tightening screw that tightens the two pincers towards one another.

The invention also proposes an aircraft comprising at least one turbofan in accordance with one of the above variants.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned features of the invention, along with others, will become more clearly apparent on reading the following description of one exemplary embodiment, said description being given with reference to the appended drawings, in which:

FIG. **1** is a side view of an aircraft comprising a turbofan according to the invention,

FIG. **2** is a perspective view of the turbofan according to the invention in the advanced and stowed position,

FIG. **3** is a perspective view of the turbofan according to the invention in the retracted and deployed position,

FIG. **4** is a schematic representation of a turbofan according to the invention, viewed in vertical section, and

FIG. **5** is a perspective view of a maneuvering system according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, the terms relating to a position refer to the direction of flow of the air in an engine which therefore flows from the front to the rear of the aircraft.

FIG. **1** shows an aircraft **10** that comprises a fuselage **12**, to each side of which is fixed a wing **14** that bears at least

one turbofan **100** according to the invention. The turbofan **100** is fixed under the wing **14** by means of a pylon **16**.

FIG. **2** and FIG. **3** show the turbofan **100** which has a nacelle **102** and a motor **20** which is housed inside the nacelle **102** and comprises a fan casing **202**. The motor **20** is represented by its rear exhaust part.

In the following description, and by convention, X denotes the longitudinal axis of the turbofan **100** that is parallel to the longitudinal axis of the aircraft **10** oriented positively towards the front of the aircraft **10**, Y denotes the transverse axis which is horizontal when the aircraft is on the ground, and Z denotes the vertical axis, these three directions X, Y and Z being mutually orthogonal.

FIG. **2** and FIG. **3** show the turbofan **100** in two different use positions, and FIG. **4** shows a schematic representation in section of the turbofan **100**.

The turbofan **100** has, between the nacelle **102** and the motor **20**, a duct **204** in which flows a bypass flow **208** coming from the air intake through a fan **300**, and which therefore flows in the flow direction from forward to rear.

The nacelle **102** has a fixed structure **206** that is mounted fixed on the fan casing **202**. Here in particular, the fixed structure **206** comprises a front frame **210** mounted around the fan casing **202** and outer panels **212** forming an aerodynamic surface which are shown as transparent in FIG. **3**, and of which a portion is cut away in FIGS. **2** and **3**.

The nacelle **102** has a mobile assembly **214** which has a mobile cowl **216** (also transparent in FIG. **3**) of which a portion is cut away in FIGS. **2** and **3** and which forms the outer walls of the nozzle.

The nacelle **102** also has a slider **218**. In this case, the slider **218** is in the form of a cylinder having openwork walls. The mobile cowl **216** is fixed to and downstream of the slider **218** with respect to the direction of flow of the flow of air in the turbofan **100**.

The slider **218** is mounted mobile in translation in a translation direction globally parallel to the longitudinal axis X on the fixed structure **206** of the nacelle **102**.

The slider **218** is mobile between an advanced position (FIG. **2**) and a retracted position (FIG. **3**) and vice versa. In the advanced position, the slider **218** is positioned as far forward as possible, with respect to the flow direction, such that the mobile cowl **216** is moved close to the outer panels **212** and to the fan casing **202** and thus forms an aerodynamic surface. In the retracted position, the slider **218** is positioned as far aft as possible, with respect to the flow direction, such that the mobile cowl **216** is moved away from the outer panels **212** and from the fan casing **202** so as to define, between them, a window **220**.

In the advanced position, the mobile cowl **216** and the outer panels **212** extend one another so as to define the outer surface of the nacelle **102**, and the mobile cowl **216** and the fan casing **202** extend one another so as to define the outer surface of the duct **204**.

In the retracted position, the mobile cowl **216** and the fan casing **202**, and the outer panels **212**, are spaced apart from one another and define, between them, the open window **220** between the duct **204** and the exterior of the nacelle **102**. That is to say, the air from the bypass flow **208** passes through the window **220** to end up outside the turbofan **100**.

The slider **218** is made to translate by any appropriate means, such as slideways between the fixed structure **206** and the slider **218**.

The nacelle **102** also comprises a set of actuators (not shown) that move the slider **218** in translation between the advanced position and the retracted position and vice versa. Each actuator is controlled by a control unit, for example of the processor type, which controls the movements in one direction or the other according to the requirements of the aircraft **10**.

Each actuator may, for example, take the form of a double-action jack (two working directions), of which the cylinder is fixed to the fixed structure **206** and a rod is fixed to the slider **218**.

In order to orient the flow of air leaving the window **220**, cascades can be fixed to the slider **218** facing the window **220**.

The fan casing **202** and the outer panels **212** form the upstream boundary of the window **220** with respect to the direction of flow and the mobile cowl **216** forms the downstream boundary of the window **220** with respect to the direction of flow.

The nacelle **102** comprises a plurality of blades **250**, each being mounted so as to be able to rotate on the slider **218** about an axis of rotation that, here, is generally parallel to the longitudinal axis X. Thus, each blade **250** is able to move between a stowed position (FIG. **2**) in which the blade **250** is outside the duct **204** and a deployed position (FIG. **3**) in which the blade **250** is across the duct **204** in order to redirect the bypass flow **208** towards the window **220**.

Each blade **250** is mounted so as to be able to move at a first end while a second end moves closer to the motor **20** when the blade **250** is deployed so as to best block the duct **204**.

The blades **250** are angularly offset from one to the next about the longitudinal axis X.

The number of blades **250**, and the shape of each of these, depend on the dimensions of the turbofan **100** and on the width of each blade **250** in order that, in the deployed position, the blades **250** block the majority of the duct **204**.

Passage from the stowed position to the deployed position is brought about by rotation of the blade **250** towards the interior of the engine **100**.

The stowed position can be adopted when the slider **218** is in the advanced position or the retracted position. The deployed position can be adopted only when the slider **218** is in the retracted position.

The slider **218** also has a maneuvering system **400** which moves each blade **250** from the stowed position to the deployed position.

Thus, operation comprises, starting from the advanced/stowed position, ordering activation of the actuators to move the slider **218** from the advanced position to the retracted position. During or at the end of this movement, the maneuvering system **400** moves the blades **250** from the stowed position to the deployed position.

Conversely, operation thus comprises, starting from the retracted/deployed position, ordering activation of the actuators to move the slider **218** from the retracted position to the advanced position. During or at the start of this movement, the maneuvering system **400** moves the blades **250** from the deployed position to the stowed position.

The use of the blades **250** mounted so as to be able to rotate on the slider **218** makes it possible to lighten the assembly compared to the use of reversal doors of the prior art.

FIG. **5** shows the maneuvering system **400** on the mobile assembly **214**, and more particularly on the slider **218**.

For each blade **250**, the maneuvering system **400** comprises a shaft **402** which is mounted so as to be mobile in rotation on the slider **218** about an axis of rotation **404**, and on which the blade **250** is fixed. In FIG. **5**, each blade **250** is truncated in order to facilitate understanding of the mechanism, and only two blades **250** are shown. Moreover,

in FIG. **5**, the slider **218** is shown in section. The axis of rotation **404** is, in this case, generally parallel to the longitudinal axis X.

For each shaft **402**, the maneuvering system **400** also comprises an arm **414** which has a first end fixed to the shaft **402** and a second end.

The maneuvering system **400** also comprises an arc **408** that is coaxial with the longitudinal axis X. The arc **408** is mounted so as to be mobile in rotation (double-headed arrow **409**) on the mobile assembly **214**, and more particularly on the slider **218**, about the longitudinal axis X.

The maneuvering system **400** also comprises an actuation system which rotates the arc **408** in one direction and in the other. In the embodiment of the invention shown in FIG. **5**, the actuation system is embodied using a rail **410** which follows the desired curve and at least one carriage **412**, where each carriage **412** is secured to the arc **408** and is mounted so as to slide on the rail **410**. The rail **410** is mounted fixed on the mobile assembly **214**. The actuation system also comprises any appropriate motive means that can allow the carriage or carriages **412** to move along the rail **410**, such as a jack mounted in articulated fashion between a carriage **412** and the mobile assembly **214**, a motor equipped with a rack gear, etc. The control unit also controls the motive means.

The connection between the carriage **412** and the rail **410** is in this case in the form of a double dovetail.

For each arm **414**, that is to say, each blade **250**, the maneuvering system **400** also comprises a lever **406** mounted in articulated fashion between the arc **408** and the second end of the arm **414**. Each articulation of the lever **406** is in this case in the form of a pivot connection about an axis parallel to the axis of rotation **404**.

Thus, a rotary movement of the arc **408** drives each lever **406** and, consequently, the rotation of each arm **414** and hence of the associated shaft **402** and blade **250**.

Each blade **250** extends in a plane generally perpendicular to the longitudinal axis X.

Each blade **250** is mounted so as to be able to move on the perimeter of the slider **218**. When the blades **250** are in the stowed position, they stack along the longitudinal axis X.

Thus, moving all of the blades **250** is relatively simple to implement, since all that is required is to rotate the arc **408**.

In the embodiment of the invention shown in FIG. **5**, the first end of each arm **414** takes the form of a pair of pincers **419** that grip the shaft **402** and comprise a tightening screw **421** that tightens the two pincers towards one another. This makes it possible to independently adjust each blade **250**.

In the embodiment of the invention shown in FIG. **5**, the slider **218** comprises a U-shaped profile **219** that is coaxial with the longitudinal axis X and open towards the longitudinal axis X. The U-shaped **219** profile forms a cage within which the blades **250** are mounted so as to be able to rotate, and where the shafts **402** pass through a wall of the U-shaped profile **219**.

The invention has been more particularly described in the case of a nacelle under a wing but can be applied to a nacelle located at the rear of the fuselage.

While at least one exemplary embodiment of the present invention(s) is disclosed herein, it should be understood that modifications, substitutions and alternatives may be apparent to one of ordinary skill in the art and can be made without departing from the scope of this disclosure. This disclosure is intended to cover any adaptations or variations of the exemplary embodiment(s). In addition, in this disclosure, the terms "comprise" or "comprising" do not exclude other elements or steps, the terms "a" or "one" do not exclude a plural number, and the term "or" means either or both. Furthermore, characteristics or steps which have been described may also be used in combination with other characteristics or steps and in any order unless the disclosure or context suggests otherwise. This disclosure hereby incorporates by reference the complete disclosure of any patent or application from which it claims benefit or priority.

The invention claimed is:

1. A turbofan having a longitudinal axis and comprising a motor and a nacelle, surrounding the motor, which comprises a fan casing, in which a duct for a bypass flow is delimited between the nacelle and the motor and in which a flow of air flows in a flow direction, said nacelle comprising:

a fixed structure fixed to the fan casing,

a mobile assembly having a mobile cowl and a slider, the mobile cowl being fixed to the slider, the slider being mobile in translation, on the fixed structure, in a direction of translation between an advanced position in which the slider is positioned such that the mobile cowl is moved close to the fan casing and a retracted position in which the slider is positioned such that the mobile cowl is moved away from the fan casing so as to define, between them, an open window between the duct and the exterior of the nacelle,

a plurality of blades, each one comprising a first end mounted so as to be mobile in rotation on the slider about an axis of rotation, and where the blades are angularly offset from one to the next about the longitudinal axis, wherein each blade is mobile between a stowed position in which the blade is outside the duct and a deployed position in which the blade is across the duct,

an assembly of actuators causing the slider to move between the advanced position and the retracted position, and vice versa, and

a maneuvering system intended to move each blade from the stowed position to the deployed position and vice versa, where the maneuvering system comprises:

for each blade, a shaft mounted so as to be mobile in rotation on the slider about an axis of rotation, and on which the blade is fixed,

for each shaft, an arm which has a first end fixed to the shaft and a second end,

an arc which is coaxial with the longitudinal axis and is mounted so as to be mobile in rotation, on the slider, about the longitudinal axis,

for each arm, a lever mounted in articulated fashion between the arc and the second end of the arm, and

an actuation system which rotates the arc in one direction and in the other.

2. The turbofan according to claim **1**, wherein the first end of each arm is formed as a pair of pincers that grip the shaft and comprise a tightening screw that tightens the two pincers towards one another.

3. An aircraft comprising at least one turbofan according to claim **1**.

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